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Chapter Forty-two

SIGHT DISTANCE

42-1.0 STOPPING SIGHT DISTANCE

<u>42-1.01 Theoretical Discussion</u>

Stopping sight distance (SSD) is the sum of the distance traveled during a driver's perception/reaction or brake reaction time and the distance traveled while braking to a stop. To calculate SSD, the following formula is used:

$$SSD = 0.278Vt + \frac{0.039\,V^2}{a} \qquad \text{(Equation 42-1.1)}$$

Where:
- SSD = stopping sight distance, m
- V = design speed, km/h
- t = brake reaction time, 2.5 seconds
- a = deceleration rate, 3.4 m/s^2

The following briefly discusses the theoretical rationale for each assumption within the SSD model:

1. <u>Brake Reaction Time</u>. This is the time interval between when the obstacle in the road can first be physically seen and when the driver first applies the brakes. Based on several studies of observed driver reactions, the assumed value is 2.5 seconds. This time is considered adequate for 90% of drivers in simple to moderately complex highway environments.

2. <u>Speed</u>. The SSD tables present a minimum value which is based on the design speed.

3. <u>Grade Adjustments</u>. AASHTO presents values to adjust the SSD for grades which, theoretically, affect braking distances. Due to the generally conservative SSD model and the terrain within Indiana, the use of the grade adjustment is not required.

4. <u>AASHTO</u>. AASHTO's *A Policy on Geometric Design of Highways and Streets* presents additional information on the assumptions used to develop the SSD model.

42-1.02 Passenger Car Stopping Sight Distance

See Figure 42-1A, Stopping Sight Distance for Passenger Cars. The designer should always attempt to meet the minimum values. Stopping sight distances exceeding those shown in Figure 42-1A should be used when practical. When applying the SSD values for passenger cars, the height of eye is assumed to be1080 mm and the height of object 600 mm. The height of object is equivalent to the height of a passenger car's taillights.

Note that the minimum SSD values for passenger cars represent the Department's Level One criteria for determining the need for design exceptions. See Section 40-8.02.

42-1.03 Truck Stopping Sight Distance

See Figure 42-1B, Stopping Sight Distance for Trucks. Such distances are based on Equation 42-1.1. In addition, the designer should consider the following when applying these truck SSD values.

1. Braking. When compared to passenger cars, a "locked-wheel" stop is considered inappropriate for trucks. Therefore, for trucks only, a "comfort" braking action is assumed.

2. Tire/Pavement Friction Factor (f). The numerical values are based on a driver control efficiency of 81%. This value is judged to be the median level between the worst-performing truck driver and the best-performing truck driver. Control efficiency is described in TRR 1208 in a paper entitled "Stopping Sight Distance Design for Large Trucks."

3. Eye/Object Height. The height of eye for a truck is assumed to be 2330 mm. The height of object is 600 mm.

4. Application. Although the truck SSD values are longer than those for passenger cars, the higher eye height tends to offset this longer distance on crest vertical curves. Therefore, the designer should only consider using truck SSD values on horizontal curves. Candidate locations requiring consideration of truck SSD include:

    a. weigh stations;

    b. rest areas;

c. truck stops;

d. truck terminals;

e. industrial parks,

f. coal (strip) mining areas;

g. railroad/highway grade crossings on high-volume truck routes (truck AADT of 2500 or greater);

h. Heavy Duty Truck Routes and other facilities with high truck traffic (i.e., routes with truck AADT's of 2500 or greater); and

i. locations that have a high accident involvement with trucks.

If the truck SSD for horizontal curves at these locations cannot be met, then a Level Two design exception will be required as described in Section 40-8.02.

42-2.0 DECISION SIGHT DISTANCE

42-2.01 Theoretical Discussion

At some sites, drivers may be required to make decisions where the highway environment is difficult to perceive or where unexpected maneuvers are required. These are areas of concentrated demand where the roadway elements, traffic volumes and traffic control devices may all compete for the driver's attention. This relatively complex environment may increase the required driver reaction time beyond that provided by the SSD values (2.5 seconds). At these locations, the designer should consider providing decision sight distance to provide an additional margin of safety. Decision sight distance reaction times range from 3 to 10 seconds depending on the location and expected maneuver. The various avoidance maneuvers used to develop Columns A through E in Figure 42-2A, Decision Sight Distance, are as follows:

1. Column A, Avoidance Maneuver A: Stop on rural road.

2. Column B, Avoidance Maneuver B: Stop on urban road.

3. Column C, Avoidance Maneuver C: Speed/path/direction change on rural road.

4. Column D, Avoidance Maneuver D: Speed/path/direction change on suburban road.

5. Column E, Avoidance Maneuver E: Speed/path/direction change on urban road.

Columns A and B of Figure 42-2A were developed using Equation 42-1.1 in Section 42-1.0. Columns C, D, and E were developed using Equation 42-2.1).

$$DSD = 0.278\ Vt \qquad \text{(Equation 42-2.1)}$$

where:

where:	*DSD*	=	decision sight distance, m
	V	=	design speed, km/h
	t	=	total time for the maneuver (reaction time + maneuver time), seconds

42-2.02 Applications

In general, the designer should consider using decision sight distance at any relatively complex location where the driver reaction time may exceed 2.5 seconds. Example locations where decision sight distance may be appropriate include the following:

1. exit/entrance gores,
2. lane drops,
3. freeway left-side entrances or exits,
4. railroad/highway grade crossings, or
5. approaches to detours and lane closures.

As with SSD, the height of eye is 1080 mm and the height of object is typically 600 mm.

42-3.0 PASSING SIGHT DISTANCE

42-3.01 Theoretical Discussion

Passing sight distance considerations are limited to 2-lane, 2-way highways. On these facilities, vehicles may overtake slower moving vehicles, and the passing maneuver must be accomplished on a lane used by opposing traffic.

The minimum passing sight distance for 2-lane highways is determined from the sum of four distances as illustrated in Figure 42-3A, Elements of Passing Sight Distance (2-Lane Highways).

Figure 42-3B, Passing Sight Distance on Two-Lane Highways, and the following provide the basic assumptions used to develop passing sight distance values.

1. Initial Maneuver Distance (d_1). This is the distance traversed during the perception and reaction time and during the initial acceleration to the point of encroachment on the left lane. For the initial maneuver, the overtaken vehicle is assumed to be traveling at a uniform speed, and the passing vehicle is accelerating at the rate shown in Figure 42-3B. The average speed of the passing vehicle is assumed to be 15 km/h greater than the overtaken vehicle. Equation 42-3.1 is used to determine d_1:

$$d_1 = \frac{t_1}{3.6}\left(v - m + \frac{a t_1}{2} \right) \qquad \text{(Equation 42-3.1)}$$

Where:
- t_1 = time of initial maneuver, sec
- a = average acceleration, km/h/sec
- v = average speed of passing vehicle, km/h
- m = difference in speed of passed vehicle and passing vehicle, km/h

2. Distance of Passing Vehicle in Left Lane (d_2). This is the distance traveled by the passing vehicle while it occupies the left lane. Assumed times for when the passing vehicle occupies the left lane are shown in Figure 42-3B. Equation 42-3.2 is used to determine d_2:

$$d_2 = \frac{v t_2}{3.6} \qquad \text{(Equation 42-3.2)}$$

Where:
- t_2 = time passing vehicle occupies the left lane, sec
- v = average speed of passing vehicle, km/h

3. Clearance Distance (d_3). This is the distance between the passing vehicle at the end of its maneuver and the opposing vehicle. Based on various studies, this clearance distance at the end of the passing maneuver is assumed to be between 30 m and 90 m.

4. Oppossing Vehicle Distance (d_4). This is the distance traversed by an opposing vehicle during 2/3 of the time passing vehicle occupies the left lane. As shown in Figure 42-3A, the opposing vehicle appears after approximately 1/3 of the passing maneuver (d_2) has been accomplished. The opposing vehicle is assumed to be traveling at the same speed as the passing vehicle. Therefore, $d_4 = 2/3\ d_2$.

42-3.02 Applications

Figure 42-3B provides the minimum passing sight distance for design on 2-lane, 2-way highways. These distances allow the passing vehicle to safely complete the passing maneuver. These values should not be confused with the values presented in the MUTCD, for the placement of no-passing zone stripes, which are based on different operational assumptions (i.e., distance for the passing vehicle to abort the passing maneuver). The designer should also realize that the highway capacity adjustment in the *Highway Capacity Manual* for 2-lane, 2-way highways is based on the MUTCD criteria for marking no-passing zones; it is not based on the percent of passing sight distance from the AASHTO *A Policy on Geometric Design of Highways and Streets*.

The designer should note that, on existing highways, it will rarely be cost effective to improve the existing passing sight distance on the facility. On rural new construction/reconstruction projects, the designer should attempt to provide passing sight distance over the length of the project consistent with the percentages shown in Figure 42-3C, Recommended Guidelines For Percent Passing on Rural Facilities. It will generally not be cost effective, however, to make significant improvements to the horizontal and vertical alignment solely to increase the available passing sight distance.

Appreciable grades can increase the sight distances required for safe passing. Passing tends to be easier for vehicles traveling downgrade because the overtaking vehicle can accelerate more rapidly; however, so can the overtaken vehicle. For upgrades, the passing sight distance should be greater than the derived minimum. Specific adjustments for use are unavailable. Consequently, the designer will need to use engineering judgment to make practical adjustments to the passing sight distances for upgrades.

Passing sight distance is measured from a 1080-mm height of eye to a 600-mm height of object. Generally, it is important to design crest vertical curves to provide for passing sight distance because of high cost where crest cuts are involved.

42-4.0 INTERSECTION SIGHT DISTANCE

Section 46-10.0 discusses the design requirements for corner sight distance at intersections at-grade.